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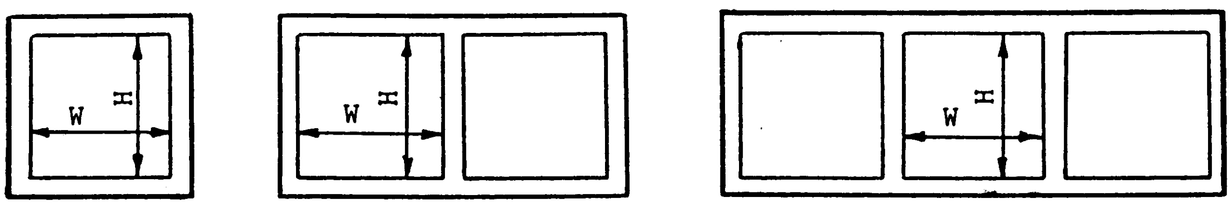
36.1 GENERAL

| Box culverts are reinforced concrete closed rigid frames which must support vertical earth and truck loads and lateral earth pressure. They may be either single or multi-cells. The most common usage is to carry water under roadways but they are frequently used for pedestrian or cattle underpasses. The minimum size for pedestrian underpasses is 8' (2.4 m) high by 5' (1.5 m) wide. Minimum size for cattle is 6' (1.8 m) high by 5' (1.5 m) wide.

| Aluminum box culverts are not permitted by the Bureau of Structures.

Typical sections for the most frequently used box culverts are shown below.



SINGLE CELL TWIN CELL TRIPLE CELL

FIGURE 36.1

Hydraulic and other requirements at the site determines the required height and area of the box. Hydraulic design of box culverts is described in Chapter 8. Once the required height and area is determined the selection of a single or multi-cell box is determined entirely from economics. Barrel lengths are computed to the nearest 6" (150 mm). For multi-cell culverts the cell widths are kept equal.

(1) Bridge or Culvert

Occasionally, the waterway opening(s) for a highway-stream crossing can be provided for by either culvert(s) or bridge(s). Consider the hydraulics of the highway-stream crossing system in choosing the preferred design from the available alternatives. Estimates of life cycle costs and risks associated with each alternative help indicate which structure to select. Consider construction costs, maintenance costs, and risks of future costs to repair flood damages. Other considerations which may influence structure-type selection are listed in Table 36.1.

Advantages	Bridges	Disadvantages
Less susceptible to clogging with drift, ice and debris		Require more structural maintenance than culverts
Waterway increases with rising water surface until water begins from to submerge superstructure		Piers and abutments susceptible to failure scour
		Susceptible to ice and frost forming on deck
	Culverts	
Grade rises and widening projects sometimes can be accommodated by extending culvert ends		Silting in multiple barrel culverts may require periodic cleanout
Minimum structural maintenance		No increase in waterway as stage rises above soffit
Usually easier and quicker to build than bridges		May clog with drift, debris or ice

TABLE 36.1

(2) Box Culvert Size Restrictions

A minimum vertical opening of 5' (1.5 m) is desirable for concrete box culverts for clean out purposes.

A maximum overall horizontal opening of 36' (10.8 m) for multi-celled concrete box culverts is considered desirable. For larger openings the design assumptions of equal load distribution may not apply.

(3) Stage Construction for Box Culverts

The inconvenience to the traveling public and the restrictions being placed on channel relocation by environmental concerns has often led to proposals for stage construction on concrete box culvert projects.

36.2 DEAD LOADS AND EARTH PRESSURE

The weight of soil above buried structures is taken as 120 pcf (18.8 kN/m^3). For the lateral pressure from the soil an equivalent fluid pressure of 60 pcf (9.4 kN/m^3) is used.

When computing the maximum positive moment in the top and bottom exterior span, use an equivalent fluid pressure of 30 pcf (4.7 kN/m^3) and for multi-cell culverts when computing the maximum negative moment over the interior wall in the end cells.

Earth pressures or loads on culverts may be computed as the weight of earth directly above the structure. A load factor of 1.3 is used for vertical earth pressure and dead loads and 1.69 (1.3 x 1.3) is used for lateral earth pressure. Vertical earth pressure is also multiplied by a soil structure interaction factor, F_e as stated in AASHTO 17.6.4.2.1. Embankment installations are always assumed.

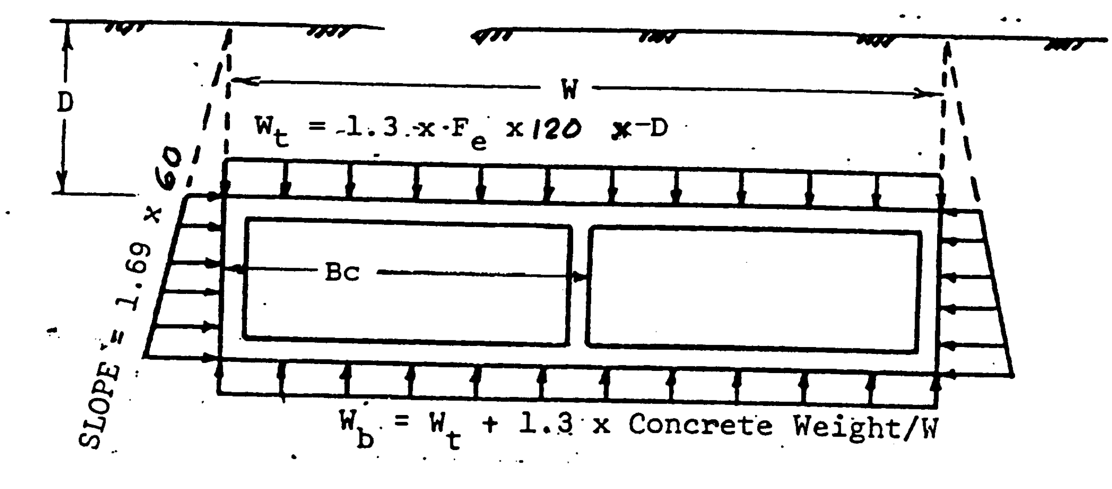


FIGURE 36.2

Figure 36.2 shows the factored earth load pressures acting on a box culvert. The earth pressure from the dead load of the concrete is distributed equally over the bottom of the box. When designing the bottom slab of a culvert do not forget that the weight of the concrete in the bottom slab acts in an opposite direction than the bottom soil pressure and thus reduces the design moments and shears. See AASHTO 17.6.4 for values of Fe shown in figure.

36.3 LIVE LOADS

Live load consists of the Standard AASHTO trucks. All culverts are designed for HS20 (MS18) loading. When the depth of fill over the box is less than 2' (0.6 m) the wheel load is distributed as in slabs with concentrated loads. When the depth of fill is 2' (0.6 m) or more the concentrated wheel loads are uniformly distributed over a square, the sides of which are equal to 1.75 times the depth of fill. When areas from several concentrations overlap, the total load is considered as uniformly distributed over the area defined by the outside limits of the individual areas.

For distributed loads two trucks are placed side by side. For single cell boxes the effect of live load may be neglected when the depth of fill is more than 8' (2.4 m) and exceeds the span length. For multiple cells it may be neglected when the depth of fill exceeds the distance between faces of end supports.

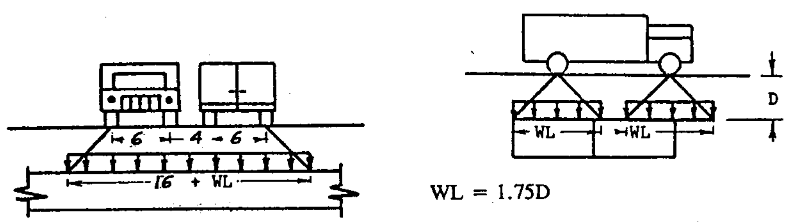
Assume that the truck passes over the box in a direction perpendicular to the centerline regardless of the culvert skew angle. The load factor for live load equals 1.3(5/3)(L + I).

(1) Concentrated Live Loads

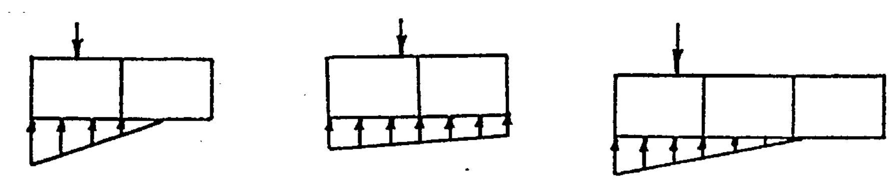
Distribute wheel load according to the formula E = 4 + .06S, where:

E = width of slab over which a wheel is distributed, ft.
S = clear span of cell, ft.

(2) Distributed Live Loads



(3) Live Load Soil Pressures



Soil pressures on the bottom of the box from live load are given a triangular or trapezoidal distribution. The resultant of the soil pressure diagram must keep the system in equilibrium.

For single and twin cell culverts, if the live load falls within the middle 1/3 of the box, distribute the soil pressure over the entire width of the box. For triple cell box culverts, if the live load falls within the middle 1/3, distribute the soil pressure between the mid-points of span 1 and 3.

(4) Impact

Impact decreases as the depth of fill increases. The following impact factors are listed in AASHTO and are used for culverts.

Depth of Fill	Impact
0 to 1' (300 mm) inc.	30%
1'-1 to 2' (310 to 600 mm) inc.	20%
2'-1 to 2'-11 (610 to 890 mm)	10%
3' (900 mm) or more	0%

(5) Location for Maximum Moment

The relative positions of the maximum ordinates of influence lines for various maximum moments are practically constant regardless of the height to width ratios of a culvert or the relative stiffnesses of the slabs and walls. It is therefore possible to assume an axle position of a truck which gives a particular maximum moment for any culvert analyzed. These axle positions are summarized below.

MAXIMUM MOMENT LOCATION	OUTSIDE SPAN AXLE LOCATIONS		
	1 - Cell	2 - Cells	3 - Cells
Top Outside Corner - Negative	.3	.35	.4
Top Inside - Negative	---	.65	.6
Bottom Outside Corner - Negative	.3	.3	.3
Bottom Inside - Negative	---	.5	.4
Top Positive - Outside Span	.5	.45	.5
Bottom Positive - Outside Span	.5	.45	.35

When span length permits, consideration must also be given to multiple axles on the culvert.

36.4 DESIGN INFORMATION

Sidesway of the box is not considered because of the lateral support of the soil.

Haunches at the center walls of multi-cell box culverts are not considered for analysis.

The centerline of the walls and top and bottom slabs are used for computing section properties and dimensions for analysis.

For skews of 20 degrees or less, culverts are analyzed as if the reinforcing steel is perpendicular to the centerline of box, even though the steel is actually placed along the skew. The only change is to the horizontal bar lengths which are increased in length by dividing by the cosine of the skew angle. For skews of over 20 degrees the reinforcing steel is placed perpendicular to the centerline of box.

Water pressure in culvert barrels is ignored.

Even though AASHTO Specifications require a stronger box for 2' (0.6 m) of fill than 4' (1.2 m), design box culverts for the actual loading condition producing the stronger box. Do not anticipate future placing or removal of fill which may require a stronger box.

The minimum thickness of the top and bottom slab is 6 1/2" (165 mm). Minimum wall thickness is based on the inside opening of the box (height) and the height of the apron wall above the floor. Use the following table to select the minimum wall thickness that meets or exceeds the three criteria in the table.

Minimum Wall Thickness (Inches)	Cell Height (Feet)	Apron Wall Height Above Floor (Feet)
8	< 6	< 6.75
9	6 to < 10	6.75 to < 10
10	10 to > 10	10 to < 11.75
11		11.75 to < 12.5
12		12.5 to 13

All slab thicknesses are rounded to the next largest ½ " - (10 mm)

All bar steel is detailed as being 2" (50 mm) clear except the bottom steel in the bottom slab. This steel is detailed as being 3" (75 mm) clear.

Top and bottom slab thicknesses are determined by shear and moment requirements. When calculating shear, live load is not considered. Slabs designed for bending moment based on the AASHTO wheel distribution are considered satisfactory in bond and shear.

A haunch is provided only when the slab depth required at the interior wall is more than 2" (50 mm) greater than that required for the remainder of the span. Minimum haunch depth is 3" (75 mm) and minimum length is 6" (150 mm). Haunch depth is increased in 3" (75 mm) increments and haunch length is increased in 6" (150 mm) increments. The haunch length is not to exceed 7 times the depth.

Fatigue requirements in bar steel are satisfied by limiting the truck service load stress to AASHTO fatigue limits using working stress analysis. In addition to the truck live load, an equivalent fluid pressure of 30 pcf (4.7 kN/m^3) or 1/2 this value is added to the outside of the box. Vertical earth pressure and concrete dead load are not considered in the fatigue analysis. The fatigue stress limit for concrete usually does not govern. The AASHTO requirements for distribution of flexural reinforcement for crack control is not required. Cracking has not been a problem for culverts designed without considering it. Reinforced concrete design is based on the strength design method and AASHTO specifications. Material strengths are:

| Concrete - fc' = 3.5 Ksi (24 MPa)
| Bar Steel - fy = 60 Ksi (420 MPa)

The slab thickness required is determined by moment or shear, whichever governs. Thickness based on moment is determined from using 37.5% of the reinforcement ratio producing balanced conditions.

The shear in the top and bottom slabs is assumed to occur at a distance "d" from the face of the walls. "d" equals the distance from the centroid of the reinforcing steel to the face of the concrete in compression. When a haunch is used, shear must also be checked at the end of the haunch.

For multi-cell culverts make interior and exterior walls of equal thickness.

For culverts under high fills use a separate design for the ends if the reduced section may be used for at least two panel pours per end of culvert. Maximum length of panel pour is 40' (12 m).

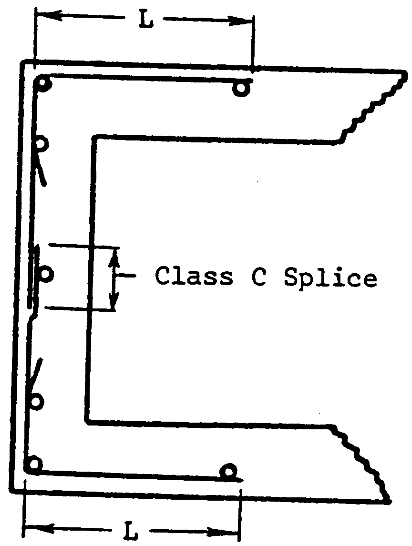
Barrel lengths are based on the roadway sections and wing lengths are based on a 2 1/2:1 slope of fill from the top of box to apron.

| Dimensions on drawings are given to the nearest 1/2" (15 mm) only.

36.5 DETAILING OF REINFORCING STEEL

To calculate the required bar steel area and cut off points a maximum positive and negative moment envelope is computed. Bar cut off points may also be determined by an approximate method based on the points of dead load contraflexure. It is assumed that the required bar lengths in the top slab are longer than those in the bottom slab. Therefore, cut off points are computed for the top slab and are also used in the bottom slab.

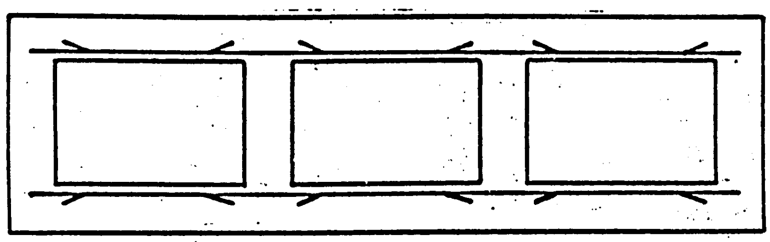
(1) Corner Steel



The area of steel required is the maximum computed from using the top and bottom corner moments and the thickness of the slab or wall, whichever controls. Identical bars are then used in the top and bottom. Top and bottom negative steel is cut in the walls and detailed in two lengths when a savings of over 1' (300 mm) in a single bar length can be obtained. Corner steel is always lapped at the center of the wall. If two bar lengths are used, only alternate bars are lapped.

Distance "L" is computed from the maximum negative moment envelope for the top slab.

(2) Positive Moment Slab Steel

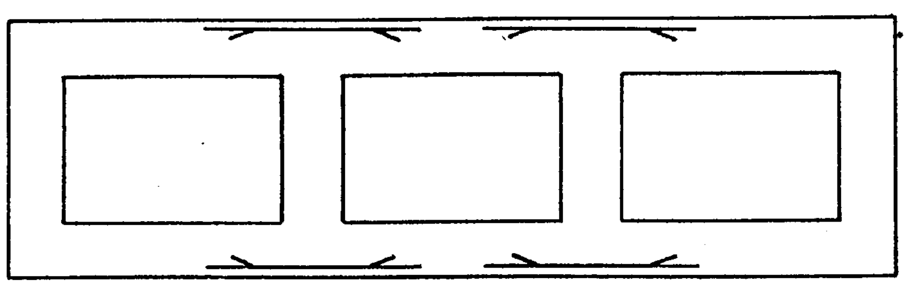


The area of steel required is determined by the maximum positive moments in each span. Top and bottom steel may be of different size and spacing. For culverts detail two bar lengths if 2' (600 mm) or more of bar steel can be saved.

When two bar lengths are detailed in multi-cell culverts, run every other positive bar across the entire width of box. If this requires a length longer than 40' (12 m), lap them over an interior wall.

The cut-off points of alternate bars are determined from the maximum positive movement envelope for the top slab. These same points are used in the bottom slab.

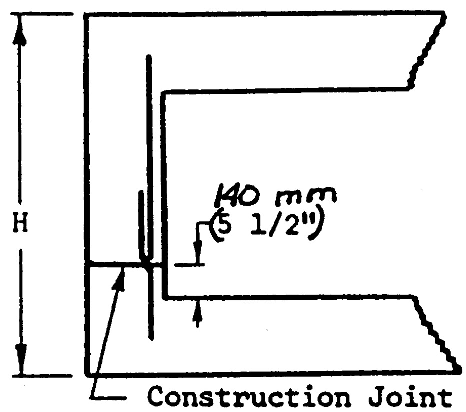
(3) Negative Moment Steel over Interior Walls



The area of steel is determined from the moment at the C/L of the interior wall and the effective depth of slab at the face of the interior wall. If the slab is haunched the steel area required at the end of the haunch must also be checked. Top and bottom steel may be of different size and spacing. If a savings in bar length of more than 2' (600 mm) can be realized, two bar lengths are detailed.

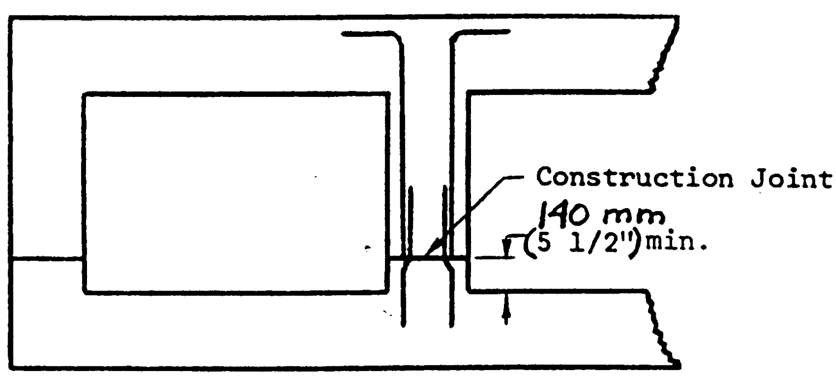
Cut off points are determined from the maximum negative moment envelope of the top slab. The same bar lengths are then used in the bottom slab. The minimum length of any bar is 2 times the development length. For culverts of 3 or more cells, if the clear distance between negative bars of adjacent spans is 1' (300 mm) or less, make the bar continuous across the interior spans.

(4) Exterior Wall Positive Moment Steel



The area of steel is determined by the maximum positive moment in the wall but a minimum of #4 (#13 bars) at 24" (600 mm) is supplied. The maximum positive moment may be assumed to occur at the .45 point from the bottom. The bars are extended into the top and bottom slab a distance of at least ten bar diameters. A construction joint, 5 1/2" (140 mm) above the bottom slab, is always used so a dowel bar must be detailed.

(5) Interior Wall Moment Steel



The area of steel is determined from the maximum moment at the top of the wall and the effective wall thickness. A minimum of # 4 (#13) bars at 24" (600 mm) is supplied. Identical steel is provided at both faces of the wall. A 1' (300 mm) 90 degree bend is provided in the top slab with the horizontal portion being just below the negative moment steel. A construction joint, 5 1/2” (140 mm) above the bottom slab, is always used so a dowel bar must be detailed. If the haunch depth is 4" (100 mm) or greater, the construction joint is placed a distance above the bottom slab equal to the haunch depth plus 2" (50 mm).

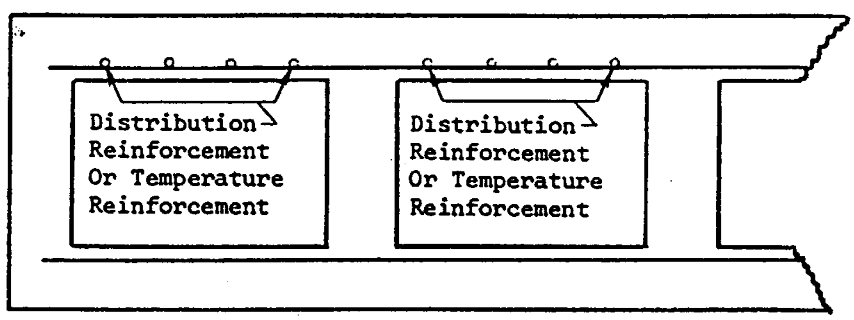
(6) Distribution Reinforcement

No distribution steel is required when the depth of fill over the slab exceeds 2' (600 mm). The amount is a percentage of the required positive moment reinforcing steel in the top slab as given by the following formula:

$$\text{Percentage} \quad \frac{55}{\sqrt{S}} \quad \frac{(100)}{(\sqrt{S})} \text{, Maximum 50\%}$$

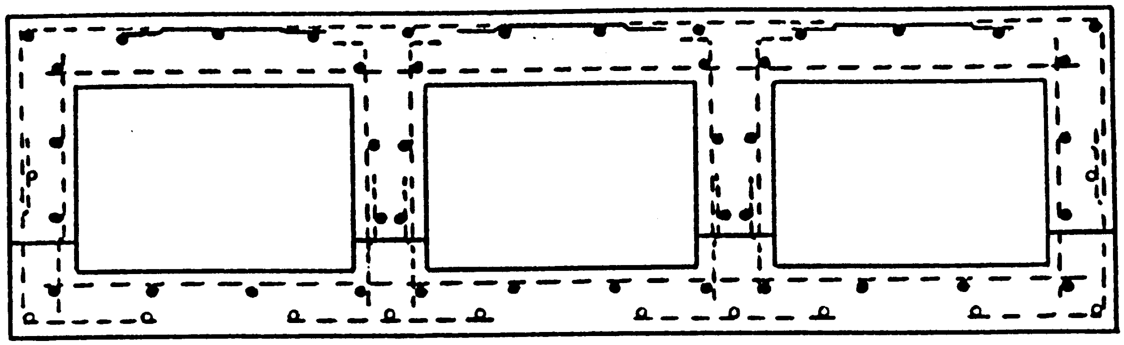
where S = the effective span length, feet (meters)

A minimum of #4 (#13) bars at 18" (450 mm) is provided for temperature reinforcement when the depth of fill exceeds 2' (600 mm).



(7) Temperature Reinforcement

Temperature reinforcement is required at the top surface of the bottom slab, the inside face of the exterior walls, both faces of interior walls, and in the top of the top slab when the depth of fill over the box is 1' (300 mm) or less. The only exception is for single cell culverts where the temperature steel in the top of the top slab is not used, unless the top slab is an integral part of wearing surface. This is because the positive dead load moment is not decreased due to live load in adjacent spans as is the case for multi-cell box culverts.



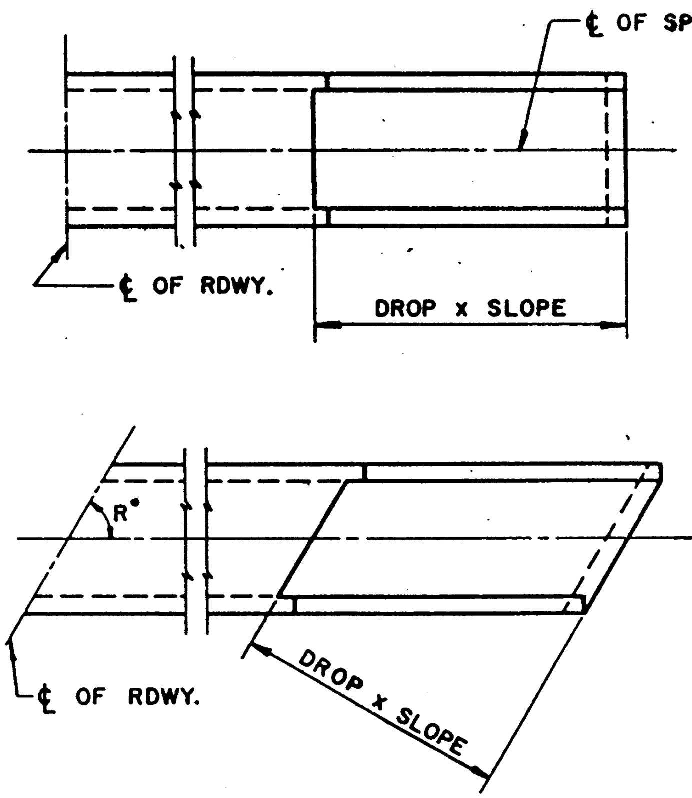
Temperature steel is always #4 (#13) bars at a maximum spacing of 18" (450 mm). The longitudinal bars shown as solid circles represent the required temperature steel. The bars shown as hollow circles are #4 bars provided primarily to support the main reinforcement. The transverse bar in the top of the top slab, shown as a solid line, is also required when top slab temperature steel is used. It is a #4 bar with a spacing not to exceed 21" (525 mm) and preferably at a spacing which is a multiple of the negative moment steel over the wall and the corner steel. When the top slab is an integral part of the wearing surface use a minimum of #4 bars at 12" (300 mm) centers in both directions in the top of the top slab.

36.6 BOX CULVERT APRONS

Five types of box culvert aprons are used. They are referred to as Type A, B, C, D and E. The angle that the wings make with the direction of stream flow is the main difference between the five types. The allowable headwater and other hydraulic requirements are what usually determines the type of apron required. Physical characteristics at the site may also dictate a certain type. For hydraulic design of different apron types see Chapter 8.

(1) Type A

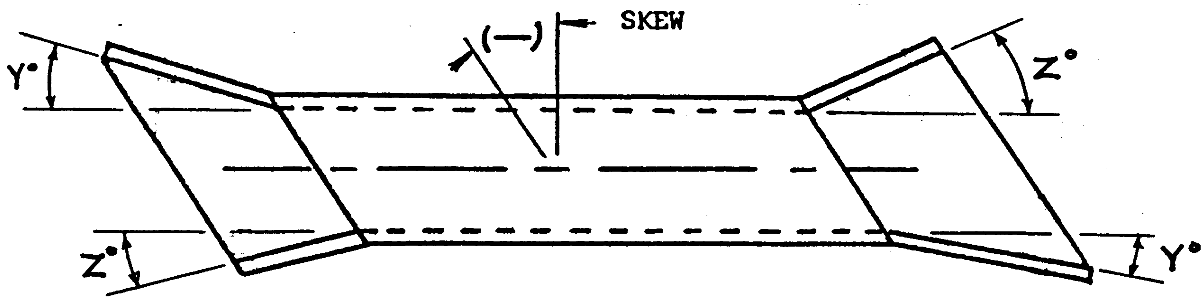
Type A, because of its poor hydraulic properties, is generally not used except for cattle or pedestrian underpasses.



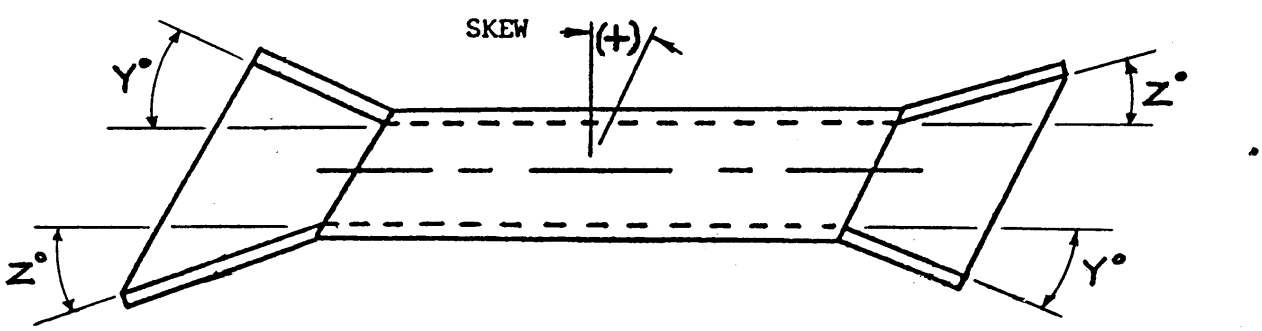
TYPE "A"

(2) Type B, C, D

Type C & D are of equal efficiency but Type C is used most frequently. Type D is used for inlets when the water is entering the culvert at a very abrupt angle. Type B is used for outlets.



SKEW		WING TYPE B		WING TYPE C		WING TYPE D	
Greater Than	To Incl.	Angle Y	Angle Z	Angle Y	Angle Z	Angle Y	Angle Z
0	7.5	15°	15°	30°	30°	45°	45°
7.5	15.0	15°	15°	25°	30°	40°	45°
15.0	22.5	10°	15°	25°	30°	35°	45°
22.5	37.5	10°	15°	20°	30°	30°	45°
37.5	45.0	10°	15°	15°	30°	25°	45°
45.0	52.5	5°	15°	15°	30°	20°	45°
52.5	67.5	5°	15°	10°	30°	15°	45°
67.5	75.0	5°	15°	5°	30°	10°	45°
75.0	82.5	0°	15°	5°	30°	5°	45°
82.5	90.0	0°	15°	0°	30°	0°	45°



SKEW		WING TYPE B		WING TYPE C		WING TYPE D	
Greater Than	To Incl.	Angle Y	Angle Z	Angle Y	Angle Z	Angle Y	Angle Z
0	7.5	15°	15°	30°	30°	45°	45°
7.5	15.0	15°	15°	30°	25°	45°	40°
15.0	22.5	15°	10°	30°	25°	45°	35°
22.5	37.5	15°	10°	30°	20°	45°	30°
37.5	45.0	15°	10°	30°	15°	45°	25°
45.0	52.5	15°	5°	30°	15°	45°	20°
52.5	67.5	15°	5°	30°	10°	45°	15°
67.5	75.0	15°	5°	30°	5°	45°	10°
75.0	82.5	15°	0°	30°	5°	45°	5°
82.5	90.0	15°	0°	30°	0°	45°	0°

(3) Type E

Type E is used primarily in urban areas where a sidewalk runs over the culvert and it is necessary to have a parapet and railing along the sidewalk. For Type E the wingwalls run parallel to the roadway just like the abutment wingwalls of most bridges. It is also used where R/W is a problem and the aprons would extend beyond the R/W for other types. Wing wall lengths for Type E wings are based on a minimum channel slope of 1.5 to 1.

(4) Wing Wall Design

| Culvert wing walls are designed for an equivalent fluid pressure of 60 pcf (9.4 kN/m^3) and a 12" (300 mm) surcharge. Load Factor Design with a total load factor of 1.69 (1.3 x 1.3) is used. The lateral earth pressure was conservatively selected to keep wing wall deflection and cracking to acceptable levels. Many wingwalls that were designed for lower equivalent fluid pressures have experienced excessive deflections and cracking at the footing. This may expose the bar steel to the water that flows through the culvert and if the water is of a corrosive nature, corrosion of the bar steel will occur. This phenomena has lead to complete failure of some wingwalls throughout the State.

| Even with the increased steel the higher wings still deflected around 3/4” at the top. To prevent this (in 1998) #7 (#22) dowel bars are added between the wing and box wall for culverts over 5’ (1.5 m) high. The dowels have a bond breaker on the portion that extends into the wings.

| For wing heights of 7' (2.1 m) or less determine the area of steel required by using the maximum wall height and use the same bar size and spacing along the entire wing wall length. The minimum amount of steel used is #4 (#13) bar at 12" (300 mm) spacing. Wingwall thickness is made equal to the barrel wall thickness.

| For wing heights over 7' (2.1 m) the wall length is divided into two or more segments and the area of steel is determined by using the maximum height of each segment. Use the same bar size and spacing in each segment.

| Shrinkage and temperature reinforcement shall be used on the front face of <u>all</u>
| wingwalls.

36.7 BOX CULVERT CAMBER

Camber of culverts is a design compensation for anticipated settlement of foundation soil beneath the culvert. The culvert strength has little effect on this settlement and is ignored. Responsibility for the recommendation and calculation of camber belongs to the district soils section. Severe settlement problems with accompanying large camber are to be checked with the Geotechnical Section.

Calculation of settlements is based on Terzaghi's theory of consolidation. Using Terzaghi's theory it is possible to reasonably estimate the probable settlement, (or decrease in volume), caused by the roadway embankment of a compressible layer of soil beneath a culvert. If several different compressible layers exist under the box, the settlement of each layer is computed separately. The total settlement is the summation of the settlements of each layer.

The compressible layers of material may not be identical along the entire length of the box. It may be necessary to calculate the settlement at more than one point along the length of the box.

(1) Computation of Settlement (shown in English Units)

Settlement of a compressible layer is computed from the following basic consolidation equation:

$$S = H \log_{10}\left[\frac{P_o + \Delta p}{P_o}\right] \quad \frac{C_c}{1 + e_o} \quad \text{where}$$

S = settlement in feet

H = thickness of compressible layer in feet

P_o = initial stress at the midpoint of the compressible layer. This includes buoyancy of soils below water table, Lbs./sq. ft.

Δp = increase in stress due to the fill construction, Lbs./sq. ft.

e_o = initial void ratio at pressure P_o

C_c = compression index which is a measure of the compressibility of a soil. It is the slope of the straight-line part of the stress-void ratio curve from a consolidation test.

A further description of the above equation and consolidation tests can be found in most textbooks on soil mechanics.

For preliminary investigations C_c can be determined from the following approximate formulas:

Non organic soils: $C_c = .007\ (LL-10)$

Organic soils: $C_c = .007$ (MOISTURE CONTENT)

where LL = liquid limit expressed as whole number and moisture content is expressed as a whole number, although both are percents by weight.

If the in-place moisture content approaches the plastic limit the computed C_c is decreased by 75%. If the in-place moisture content is near the liquid limit use the computed value. If the in-place moisture content is twice the liquid limit the computed C_c is increased by 75%. For intermediate moisture contents the percent change to the computed C_c is determined from a straight line interpolation between the corrections mentioned above.

If settlements computed by using the approximate value of C_c exceed 1.5 feet, a consolidation test is performed. As in-place moisture content approaches twice the liquid limit, settlement is caused by a shear failure and the consolidation equation is no longer applicable.

The consolidation equation is applied to only compressible silts and clays. Sands are of a lower compressibility and no culvert camber is required until the fill exceeds 25 feet. When the fill exceeds 25 feet for sand, a camber of .01 feet per foot of fill is used.

(2) Configuration of Camber

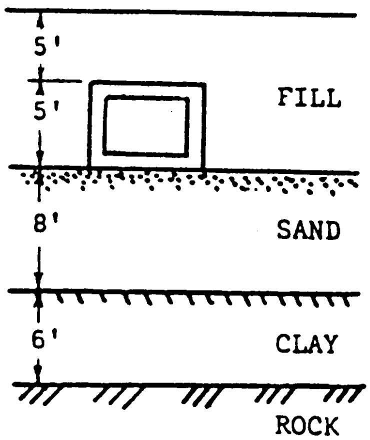
The following guides are to be followed when detailing camber.

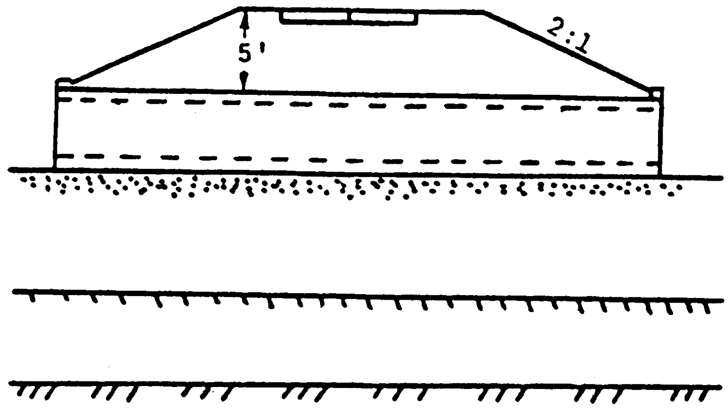
(a) It is unnecessary to provide gradual camber. "Brokenback" camber is closer to the actual settlement which occurs.

(b) Settlement is almost constant from shoulder point to shoulder point. It then reduces to the ends of the culvert at the edge of the fill.

(c) The ends of the culvert tend to come up if side slopes are steeper than 2 1/2 to 1. With 2 to 1 side slopes camber is increased 10% to compensate for this rise.

(3) Numerical Example of Settlement Computation





A box culvert rests on original ground consisting of 8' of sand and 6' of clay over bedrock. Estimate the settlement of the culvert if 10 foot of fill is placed on the original ground after the culvert is constructed. The in-place moisture content and liquid limit equal 40%. The initial void ratio equals .98. The unit weight of the clay is 105 lb/cu. ft. and that of the fill and sand is 110 lb/cu.ft. There is no water table.

P_o = 8 x 110 + 3 x 105 = 1195. lb/cu.ft.

Δp = 10 x 110 = 1100. lb./cu.ft.

$$S = H \log_{10}\left[\frac{P_o + \Delta p}{P_o}\right] \quad \frac{C_c}{1 + e_o}$$

C_c = .007 (30) = .21 (approximate value)

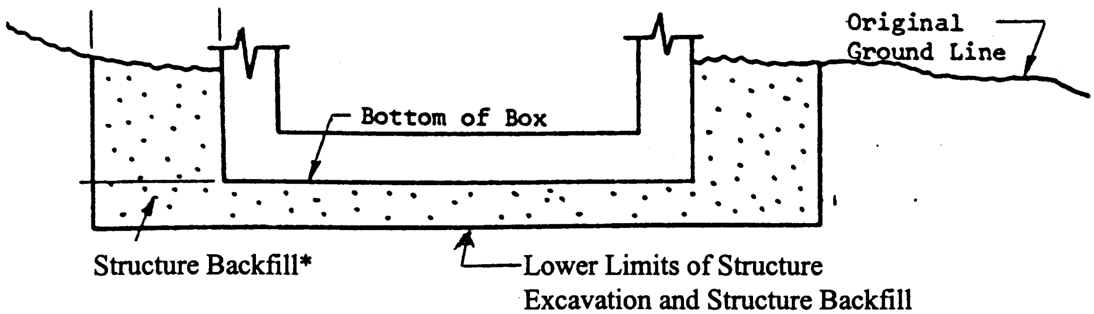
$$S = 6 \log_{10}\left[\frac{1195 + 1100}{1195}\right] \quad \frac{.21}{1.98}$$

$$S = 6 \log_{10} 1.92(.106) = 6x.283x.106 = .18 ft.$$

36.8 BOX CULVERT STRUCTURAL EXCAVATION AND STRUCTURE BACKFILL

All excavations for culverts and aprons, unless on bedrock or fill, are undercut a depth of 6" (150 mm). The upper limit of excavation is the existing ground line.

All spaces excavated and not occupied by the new structure are backfilled with structural backfill to the elevation and section existing prior to excavation within the length of the box. The backfill is placed to help eliminate settling problems on culverts. Backfill is placed in the undercut area under the apron. Usually 6" (150 mm) of structural backfill is placed under all boxes for construction purposes, which is covered by specification.



* Structure Backfill, No. 2 Washed Stone or Breaker Run Stone may be used to support culverts.

No backfill is placed under the box for culverts built on fills. The purpose of the backfill is to provide a solid base to pour the bottom slab. It is assumed that fill material provides this base without the addition of backfill.

36.9 BOX CULVERT HEADERS

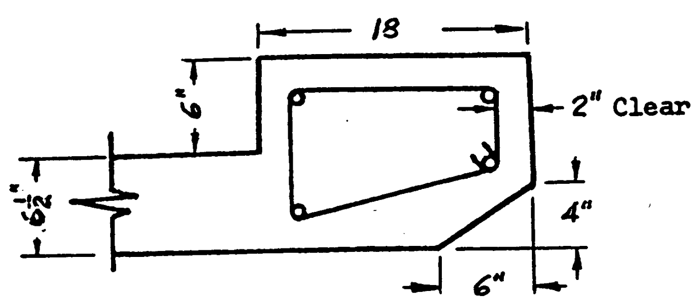
For skews of 20 degrees and less the main reinforcing steel is parallel to the end of the barrel. A header is not required for structural purposes but is used to prevent the fill material from spilling into the apron. A 12" (300 mm) wide by 6" (150 mm) high (above the top of top slab) header with nominal steel is therefore used for skews of 20 degrees and less on the top slab. No header is used on the bottom slab.

For skews over 20 degrees the main reinforcing is not parallel to the end of the barrel. The positive reinforcing steel terminates in the header and thus the header must support, in addition to its own dead load, an additional load from the dead load of the slab and fill above it. A portion of the live load may also have to be supported by the header.

The calculation of the actual load that a header must support becomes a highly indeterminate problem. For this reason a rational approach is used to determine the amount of reinforcement required in the headers. The design moment strength of the header must be equal to or greater than 1.3 times the header dead load moment (based on simple span) plus 1.3 times a live load moment from a 16 kip (72 kN) load assuming .5 fixity at ends.

To prevent a traffic hazard culvert headers are designed not to protrude above the ground line. For this reason the height of the header above the top of the top slab is allowed to be only 6" (150 mm). The width of the header is standardized at 18" (460 mm).

The header in the following sketch gives the design moment strengths listed using d = 8.5" (215 mm).



BAR SIZE	ULTIMATE MOMENT ft.-kip (kN-m)
#6 (#19)	31.7 (43.0)
7 (22)	42.1 (57.1)
8 (25)	54.0 (73.2)
9 (29)	66.5 (90.2)
10 (32)	80.9 (109.7)

The following size bars are recommended for the listed header lengths where "HEADER LENGTH" equals the distance between C/L of walls in one cell measured along the skew.

HEADER LENGTH	BAR SIZE *
To 10' (3 m)	#7 (#22)
Over 10' (3 m) to 13' (3.9 m)	8 (25)
Over 13' (3.9 m) to 16' (4.8 m)	9 (29)
Over 16' (4.8 m) to 20' (6 m)	10 (32)

* Use the bar size listed in each header and place 2 bars on top and 2 on bottom. Use a header on both the top and bottom slab. See Standard 36.3 for details.

36.10 CONSTRUCTION ISSUES

(1) Weepholes

Investigate the need for weepholes for culverts in cohesive soils. These holes are to relieve the hydrostatic pressure on the sides of the culverts. Where used, place the weepholes 1' (300 mm) above normal water elevation but a minimum of 1' (300 mm) above the lower sidewall construction joint. Do not use weepholes if they are closer than 1' (300 mm) to the top slab.

(2) Cutoff Walls

Where dewatering the cutoff wall in sandy terrain is a problem, the concrete may be poured in the water and this can be noted on the plans.

(3) Nameplate

Designate a location on the wingwall for placement of the nameplate. Locate nameplate on the first right wing traveling in the Cardinal direction (North/East).

(4) Plans Policy

Box Culvert plans will be detailed for only cast-in-place reinforced concrete where site geometry, hydraulic, and soils conditions are acceptable.

Precast concrete box culverts have not been cost effective in comparison to cast-in-place concrete and in general will not be detailed on plans. If an exception occurs warranting the use of precast box sections; contact the Bridge Office for further guidance.

(5) Rubberized Membrane Waterproofing

When the Standard requires membrane waterproofing, place the bid item "Rubberized Membrane Waterproofing" on the final plans along with the bid quantity in square yards ("square meters").

36.11 PRECAST BOX CULVERTS

In general, structural contractors prefer cast-in-place culverts while grading contractors prefer Precast culverts. Precast culverts have been more expensive than cast-in-place culverts. Box culverts that are 4 feet wide by 6 feet high or less are considered roadway culverts. All other culverts require a B or C number along with the appropriate plans. All culverts requiring a number should be processed thru the Bureau of Structures.

In situations where Precast culverts are the obvious choice, plans are not required for a cast-in-place culvert. The designer may show the location along with a Special Provision requiring materials, design and fabrication to be in accordance with AASHTO Designation M259. If the box has less than two feet of fill and subject to AASHTO loading, it must conform to AASHTO Designation M273. It is not necessary to submit design plans but the Special Provision must require the contractor to submit shop plans to the Bureau of Structures for approval.

For most cases plans are shown for cast-in-place culverts with a note allowing the contractor to propose a Precast culvert.

If a Precast culvert is used, Special Provisions should require the contractor to submit shop plans sealed by a professional engineer to the Bureau of Structures for approval. The plans must be in accordance with the Wisconsin Bridge Manual and Standards.